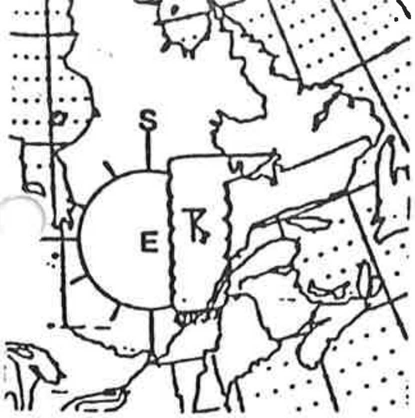

NOTE TECHNIQUE

RÉGION DU QUÉBEC

<u>SYNOPTIC PATTERN RECOGNITION AND PARTIAL THICKNESS TECHNIQUES AS A TOOL FOR PRECIPITATION TYPES FORECASTING ASSOCIATED WITH A WINTER STORM</u>

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AVRIL 1993
NUMÉRO 93N-002

SYNOPTIC PATTERN RECOGNITION AND PARTIAL THICKNESS TECHNIQUES AS A TOOL FOR PRECIPITATION TYPES FORECASTING ASSOCIATED WITH A WINTER STORM

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RÉSUMÉ

Une technique de reconnaissance de patron synoptique permettant de déterminer les types dominants de précipitations est presentée. Cette technique consiste à reconnaître certains traits caractéristiques tels: positions relatives et trajectoires des systèmes, gradient et orientation des épaisseurs 1000-500 mb, circulation à 500 mb. D'autre part une méthode objective d'évaluation des types de précipitations est utilisée conjointement. Cette dernière fait appel aux épaisseurs partielles critiques 1000-850 mb et 850-700 mb telles qu'établies par Koolwine(1975)*. Celle-ci est utilisée au Centre météorologique du Québec (C.M.Q.) où quelques ajouts lui ont été apportés: addition d'une valeur d'épaisseur partielle critique, influence du mouvement vertical et du drainage d'air froid par les vents d'est, effets locaux, stage d'évolution d'un système. L'utilisation simultanée de ces deux techniques a conduit à une amélioration globale de la qualité des prévisions émises par le C.M.Q.

ABSTRACT

A synoptic pattern recognition technique allowing the determination of the dominant precipitation types is presented. This technique consists of identifying some caracteristics such as: relative position and tracks of weather systems, gradient and orientation of 1000-500 mb thicknesses, 500 mb circulation. Additionally, an objective technique for precipitation types forecasting is used simultaneously. It calls upon the partial thicknesses 1000-850 mb and 850-700 mb as studied by Koolwine(1975)*. It is used at the Centre météorologique du Québec (C.M.Q.) where a few additional features were identified: an additionnal critical partial thickness value, the influence of vertical motion and of cold air advection by easterlies, local effects, stage of development of a system. The simultaneous use of those two trchniques led to a global upgrade in the quality of the forecasts issued by the C.M.Q.

1. INTRODUCTION

One of the most challenging problems facing the operational meteorologist in the day to day forecast is the determination of each precipitation type (rain, freezing rain, snow, etc.) associated with a winter storm. In the following, we will present two techniques currently used at the Quebec Weather Center. Both are used simultaneously to decide what will be the precipitation type, what area will be affected and how significant each element will be. The development of such a technique has been made possible since the local management recognized the importance of creating a specialized desk dealing with winter season forecast problems. Since freezing rain is one of the most hazardous weather elements, its forecast must be as accurate as possible.

2. SYNOPTIC PATTERN RECOGNITION TECHNIQUE

2.1 Goals

- Determine at first glance what are going to be the most significant types of precipitation over the Quebec region areas of responsibility.
- Discriminate between a ZR event (freezing rain) and an IP/S event (ice pellet/snow).

2.2 Advantages

- Uses synoptic fields as seen on analysis and prognosis of upper air and MSL charts.
- If numerical prognosis are reasonably good, it may be used up to 48 hours with a great deal of confidence.
- Allows the public forecaster to mention freezing precipitation well in advance and conversely to avoid mentioning ZR when an IP/S situation is diagnosed.

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* Koolwine, T., 1975, Freezing Rain, M.Sc. thesis, Dept. of physics, University of Toronto, 92 p.

2.3 Technique development

This technique was developed by comparing a few winter storms which produced an important ZR area with a few others which resulted in S/IP over southern Quebec, with no important ZR event. In both cases, the critical 1000-500 mb thickness of 540 dam generally delimits the northern edge of the ZR or IP area. However, the impact is highly different: an IP/S case possibly requiring more a snow/blowing snow warning instead of a ZR warning.

A study of these storms over southern Quebec allowed us to find that some synoptic features particular to important ZR storms were different from IP/S storms. Two major synoptic patterns out of six identified are shown below together with a brief description and analysis.

2.4 Description of patterns and analysis

A. IP storm over southwestern Quebec

The recognition of this type of storm does not exclude the possibility of a few hours of very light freezing rain or drizzle as the center of the low passes by, i.e. towards the end of the precipitation episode. It does indicate though that most of the precipitation will fall as snow and ice pellets. Two synoptic patterns of this type were recognized. The following will give details on only one of these two patterns since they differ mainly by the 500 mb circulation, the remaining features being mostly the same.

A.a: Confluent circulation type:

Typical features: (cf. fig. 1. to fig. 4.)
- Strong 500 mb confluent circulation over Quebec.
- Strong 1000-500 mb thickness gradient along the St-Lawrence valley. (NE-SW)
- High pressure system moving over northern Quebec and remaining in this area.
- Surface low or wave moving over extreme southern Quebec or just south of the Quebec border.
- Northeasterly surface winds enhanced by the NW-SE to WNW-ESE orientation of isobars.

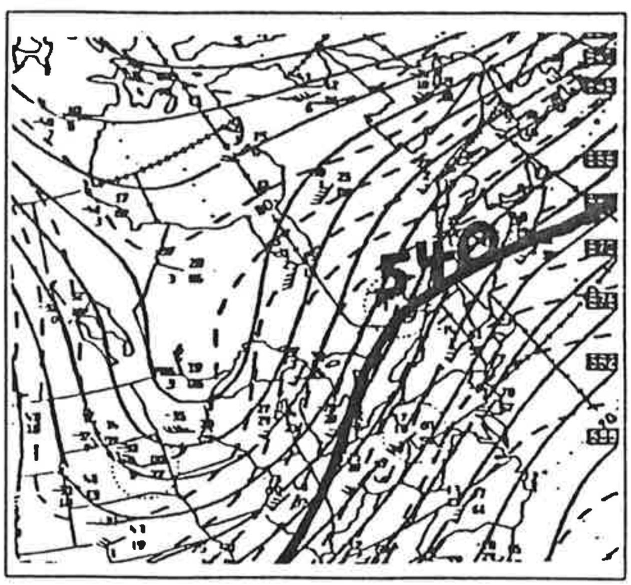

Fig. 1: Confluent circulation type.
500 mb analysis, 10/12/86, 00Z
— — —1000-500 mb thicknesses
————500 mb heights

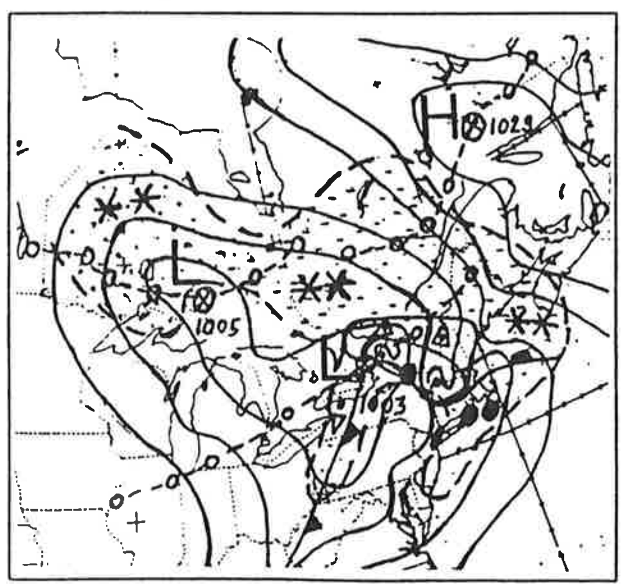

Fig. 2: Confluent circulation type
Surface analysis
10/12/86, 00Z
o--o--o Low/high tracks

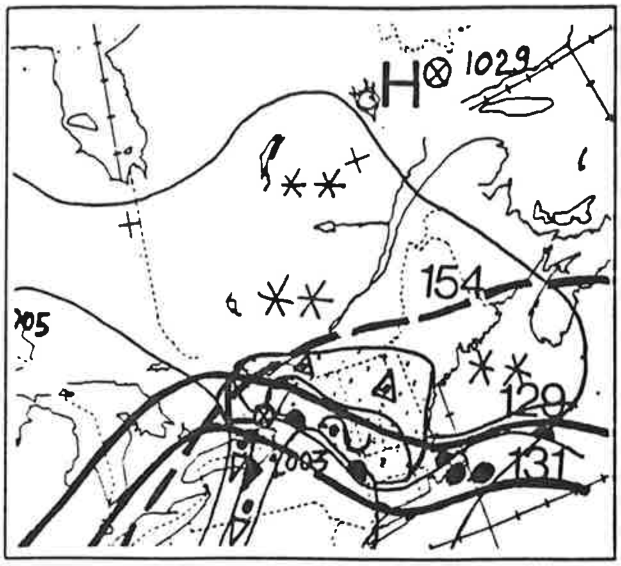

Fig. 3 10/12/86, 00Z: Correlations between precipitation types and partial thicknesses.

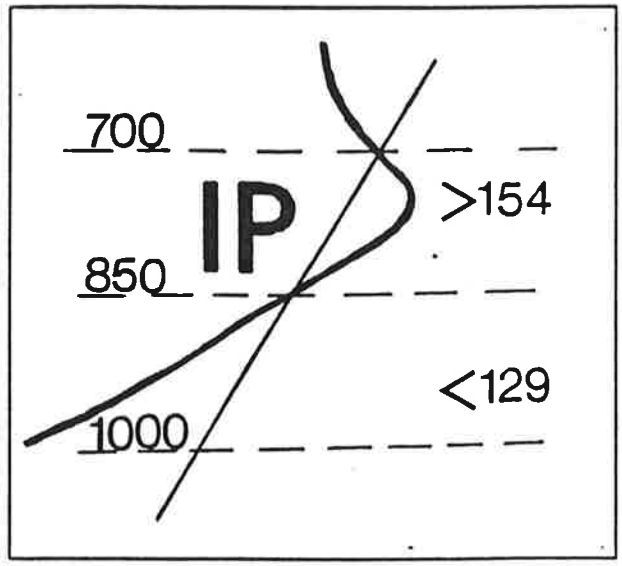

Fig. 4 Typical temperature profile in the IP area.

An analysis of such a synoptic structure shows the following:

- The thickess gradient implies an important surface temperature gradient along the St-Lawrence valley;
- Consequently, with the favourable isobaric gradient, an important low level cold air advection toward the upper St-Lawrence valley is established;
- The 540 dam thickness moving over extreme southwestern Quebec is an indication of warm air with above zero temperatures overrunning this sector.

The result will generally be an IP temperature profile over southwestern Quebec (see fig. 4). The extent of the cold layer trapped at low level will be greater than the shallow warm layer with above zero temperatures (generally well above 850 mb). Moreover, before the arrival of the warm layer aloft, the precipitation will be snow accompanied by moderate to strong northeasterly surface winds generally causing drifting and blowing snow.

That is the reason why this type of situation should be identified well in advance with the help of the numerical prognosis. A good identification will help the forecaster to focus on the most significant weather event. In this case, it might require a snow-blowing snow warning rather than a freezing rain warning even though the 540 dam thickness is forecast in proximity.

B. ZR storm over southwestern Quebec

In comparison to the above IP type, the following case will describe the typical and the more common synoptic set-up for a significant freezing rain event over southern Quebec. Three more synoptic patterns were identified but are not presented here.

B.a: Type ZR: This pattern refers to storms with the normal evolution of precipitation types: S → IP → ZR → R/L

Typical features: (cf. fig. 5. to fig. 8.)

- Moderate to weak N-S gradient of 1000-500 mb thicknesses (when compared to IP cases).

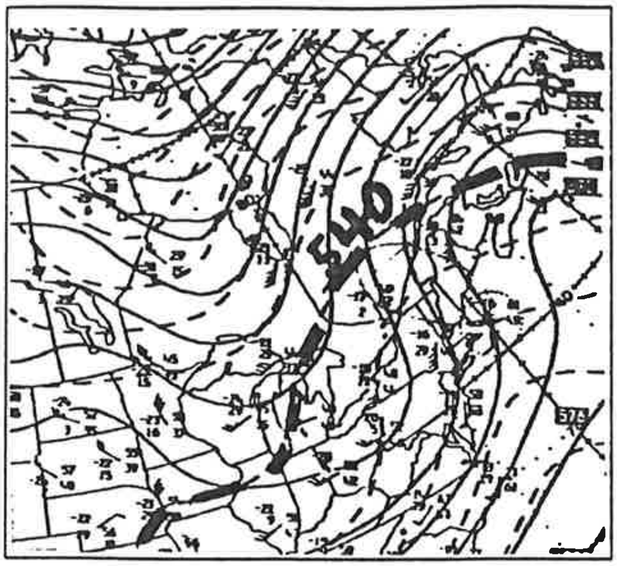

Fig. 5: Classical ZR type.
500 mb analysis, 25/12/86, 12Z
— — — —1000-500 mb thicknesses
———————500 mb heights

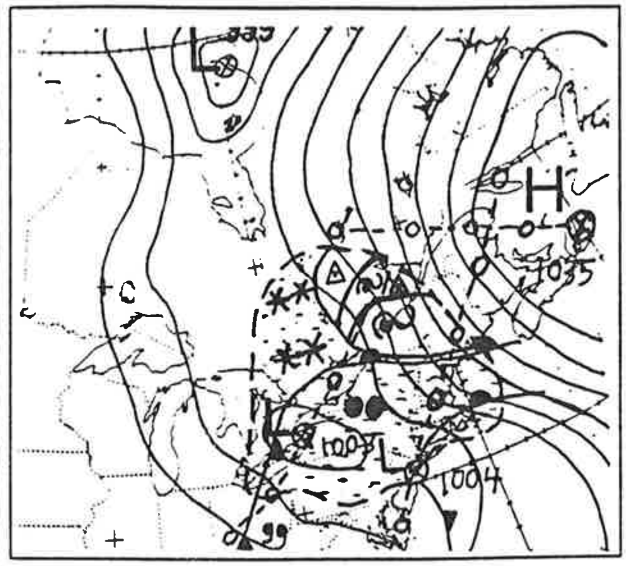

Fig. 6: Classical ZR type.
Surface analysis
25/12/86, 12Z.
o--o--o Low/High tracks

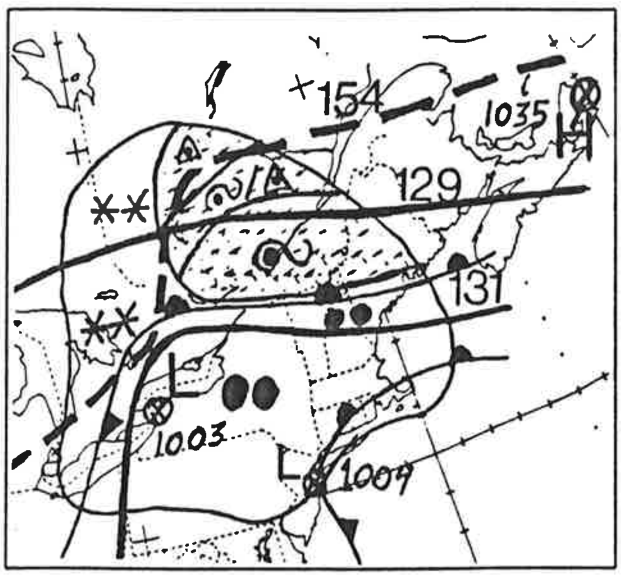

Fig. 7 25/12/86, 12Z: Correlations between precipitation types and partial thicknesses.

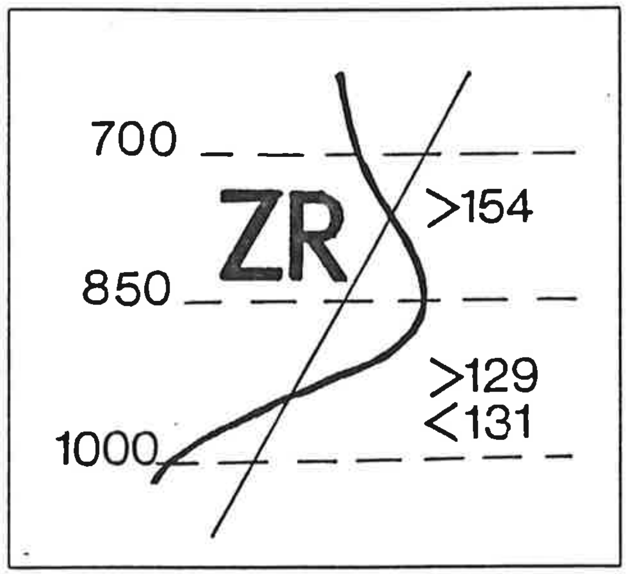

Fig. 8 Typical temperature profile in the ZR area.

- Surface low with a general SW-NE track over southern Quebec or just south of Quebec.
- High pressure system over northern Quebec moving southeastward over Maritimes as precipitation reaches the souhwestern Quebec regions.
- Surface ridge extending northward from the high pressure system.

The important differences between this pattern and the IP patterns are in the track of the high pressure system and in the intensity of the thickness gradient. The high pressure center tracking southeastward to the south of the St-Lawrence and the surface ridge being oriented more northward than northwestward or even westward allow the isobars to be more north-south throughout the St-Lawrence valley which is an orientation less favourable to strong northeasterly winds. Also, this type of relative positioning of the systems results in a weaker thickness gradient along the valley than in the IP patterns and causes the orientation of the thicknesses to be more east-west than southeast-northwest. These caracteristics imply:

- a weaker temperature gradient along the valley.
- a weaker low level cold air advection because of weaker northeasterly winds.
- a circulation much more favourable to warm air advection at all levels.

In these situations, we will generally obtain a deeper and more extensive warm layer aloft as well as a shallower cold layer near the surface, which will give a typical ZR temperature profile (cf. fig. 8.). Even though the northeasterly winds are weak, they will persist in the valley as long as there is a pressure gradient with higher pressure eastward. The result is a warm front with a slow northward motion thus enhancing the freezing rain period in the regions along the valley.

2.5. Conclusion

Obviously, not all storms can be classified in one of the major synoptic patterns identified. Nevertheless, it does help in many cases to determine the dominant types of precipitation associated with a storm. When used with the partial thickness technique presented below it greatly assists the decision process when forecasting precipitation type.

3. PARTIAL THICKNESS TECHNIQUE

3.1 Goals

- Define precisely the position of each type of precipitation related to a low.
- Determine if a freezing rain warning is necessary.

3.2 Advantage

- Uses shallower thicknesses than the traditional 1000-500 mb thicknesses allowing a better resolution in the vertical temperature profile.

3.3 Technique development and description

T. Koolwine, in his master thesis, found that critical partial thicknesses associated with freezing precipitation over southern Ontario generally fall within certain critical values. For obvious reasons the 1000-850 mb and 850-700 mb thicknesses were used as predictors of low level cold air and mid level warm air respectively. He found that for freezing precipitation both of the following conditions need to be satisfied:

$$1000\text{-}850 \text{ mb thickness} < 1314 \pm 6 \text{ m}$$
$$850\text{-}700 \text{ mb thickness} > 1539 \pm 3 \text{ m}$$

After studying a few freezing rain cases, D. Bachand* found that these critical values seemed to be valid over the Quebec region as well. For convenience, he used the values 131 dam and 154 dam. He also found a second low level critical thickness value at which, for a 850-700 mb thickness greater than 154 dam, freezing rain would change to ice pellet. This second critical 1000-850 mb thickness is 129 dam (refer to figs. 3, 4, 7 and 8 to see how these critical thicknesses generally correlate to precipitation types and temperature profiles).

* D. Bachand, 1986, Unpublished notes on freezing rain forecast with partial thicknesses, Quebec Weather Center.

It is important to note that in the presence of a low level temperature inversion (generally ahead of a warm front) a 850-700 mb thickness greater than 154 dam implies temperature greater than zero somewhere within that layer and that, similarly, a 1000-850 mb thickness greater than 129 dam implies temperature greater than zero below 850 mb. Conversely, in a low level temperature inversion situation, a 1000-850 mb thickness smaller than 129 dam implies that all the layer 1000-850 mb is at a temperature below the freezing mark with a rather cold surface temperature. The latter indicates an ice pellet situation associated with a warm layer above 850 mb.

A. Cantin studied most of the freezing rain and/or ice pellet producing storms of the 1987-1988 winter season as well as a few cases of the 1988-1989 season. The basic conditions stated above seemed to discriminate the freezing rain/ice pellet areas quite nicely, but there were still some exceptions that would fall in and even extend the error margin stated by Koolwine specially for the low level thickness value. The interval 1308 to 1320 for the change of freezing rain to rain is sometimes too large a gap to be used extensively in the operational environment. In the same manner, there is an error margin for the critical value of 129 dam as a threshold for the change of ice pellet to freezing rain.

Something else was then needed to determine more precisely and with more confidence the limits of change of precipitation from one type to another. The examination of all these cases suggested that the intensity of the upward vertical motion related to the intensity of the precipitation was an important parameter to consider in the determination of precipitation type. Stewart and King (1987)** showed clearly this effect with a numerical simulation of precipitation types with different size of snowflakes. The intensity of the cold air advection at low level by easterlies enhanced by the presence of valleys, especially the St-Lawrence, is also important and is related to the intensity of the vertical motion in the boundary layer. The effect of vertical motion on precipitation types according to the researchers and confirmed by observations can be summarized qualitatively as follows:

- increasing upward vertical velocity leads to more solid precipitation type: for example, with the same partial thicknesses or vertical temperature profile, precipitation might change from ZR to IP or from R to S.
- conversely, in a region with a general IP temperature profile, precipitation may be observed as ZR if upward vertical motion and low level cold air advection become weaker or even tend toward zero.

In the following section, the summary of these results is presented in a general table describing the most probable types of precipitation according to the partial thicknesses and to the intensity of the upward vertical velocity and low level cold air advection. The vertical velocity and drainage have not been quantified yet and must be evaluated subjectively by the meteorologist.

3.4 Summary of results

The table 1. summarizes the results, showing the operational correlations as currently used at the Quebec Weather Center. The first part of the table refers to cases where there is no overlapping of the critical thicknesses whereas the second part refers to cases with overlapping of critical thicknesses making freezing precipitation possible.

** Stewart R. E. and P. King, 1987, Freezing precipitation in winter storms, Monthly Weather Review, Vol. 115 No. 7, pp. 1270-1279

Table 1. Precipitation types according to partial thickness intervals and upward vertical velocity (evaluated subjectively).

(): Types between parentheses are possible but not dominant except for those with one of the three specific following conditions:
#1: Warm sector or southerly winds
#2: Close to the 154 dam
#3: Ahead of warm front and >152 dam
X/Y: The two types (or more) are equally possible

	THICKNESS 850-700	THICKNESS 1000-850	PRECIPITATION TYPES Signif. up. V.V. and /or signif. low lvl. cold air advection	 Weak up. V.V. and near zero low lvl. cold air advection
WITHOUT OVER-LAPPING	<154	<129	S	S (IP/ZL)
	<154	129-131	S (R #1)	R/S (R #1)
	<154	>131	R	R
WITH	<154	<129	S (IP #2)	S (IP/ZR #2)
	<154	129-131	S/IP (ZR #2) (R #1)	IP/S (R #1) (ZR/ZL #3)
	<154	>131	R	R
OVER-LAPPING	>154	<129	IP (S #2)	ZL/ZR/IP
	>154	129-131	ZR (IP #2)	ZR/ZL (R/L)
	>154	>131	R (often >132)	R

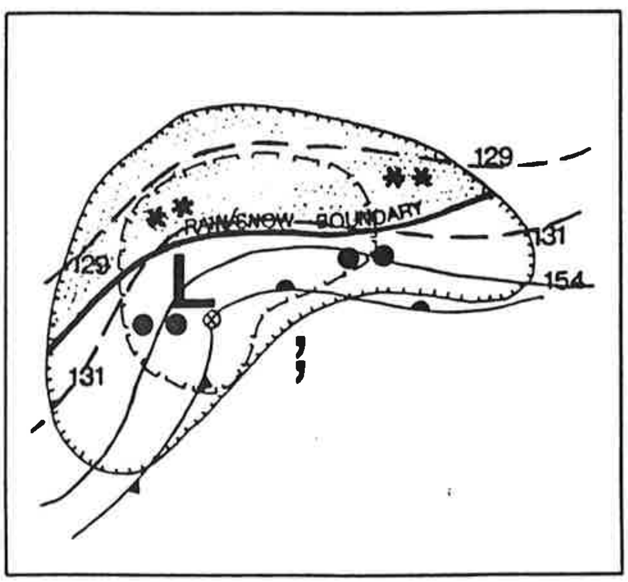

Fig. 9 Mature low without overlapping of the partial thickness lines and associated precipitation types.
ıııııııııı : Precipitation area
ᑌ ᑌ ᑌ ᑌ : Area of strong VV
— — — : 1000-850 mb thickness
——— : 850-700 mb thickness

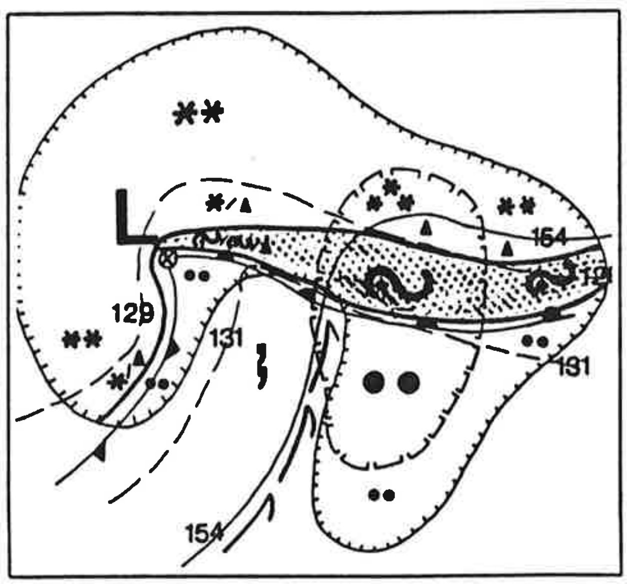

Fig.10 Occluding low with overlapping of the partial thickness lines and associated precipitation types.
(same as fig. 9.)

A. Partial thicknesses and precipitation types ahead of a winter storm.

A.a With no overlapping of critical thicknesses.(cf. fig. 9.)

Generally, when there is no overlapping of the critical lines (part 1 of table 1), the R/S boundary will be close to the 131 dam (which is generally just north of the 154 dam) if there is sufficient vertical motion and if the system is not occluded. Otherwise, it could be anywhere between the 129 dam and 131 dam specially if there is a local effect such as a large open water body. In this case the 540 dam has proved to be a good indicator for non-occluded sytems. The 129 dam seems to be the lowest low level thickness value at which liquid precipitation is possible (except for drizzle, freezing or not) and it generally matches the 528 dam 1000-500 mb thickness line.

A.b. With an overlapping of the critical thickness lines.(cf. fig. 10.)

A.b.1: R/ZR boundary:

In cases with strong vertical motion, this boundary is generally between the 131.0 to 131.5 dam and sometimes near the 132 dam. When the vertical motion becomes weaker the boundary will move towards lower thickness values between 131 and 129 dam specially if the low levels cold air advection approaches zero. In the occluded case shown, even though the mid level thickness is lower than 154 dam just ahead of the low north of the warm front the precipitation remains a mixture of very light freezing rain, freezing drizzle and ice pellet. This can be explained as follows: (1) surface winds remain easterly keeping cold air very close to the surface in the boundary layer; (2) precipitation rate is light; (3) the warm air layer is at a lower level, giving a 850-700 mb thickness lower than 154 dam. However, for values lower than 152 dam the airmass becomes unstable and moderate to heavy snow showers is produced instead of light freezing precipitation.

Finally, whatever the thickness values (except if lower than 129 dam), the precipitation will change to rain if the surface winds become southerly breaking up the inversion in the boundary layer. The setting up of southerlies generally marks the arrival of the warm sector.

A.b.2: ZR / IP boundary:

With the 154 dam line north of the 129 dam, the latter generally marks the ZR/IP boundary in a significant vertical motion situation. With weaker vertical motion, the boundary is somewhere between the 154 dam and 129 dam.

A.b.3: IP / S boundary:

This boundary is in most cases indicated by the 154 dam when this line is north of the 129 dam. Otherwise the transition goes from freezing rain to snow with almost no ice pellet area.

B. Partial thicknesses and precipitation types in the wake of a winter storm.

Generally in this area there is no overlapping of the critical thickness lines and the remaining problem is to determine the transition from rain to snow. The vertical motion is also weaker, except in the comma head where snow generally falls, and, as stated above, in these cases the rain-snow boundary can be anywhere between the 129 and 131 dam. Nevertheless, some indications may help determining this boundary:

- The indication of a surface trough trailing the low would be a favoured location since winds ahead of the trough remain south to southwest.

- If a strong west to northwest circulation prevails southwest of the low with no well-marked trough, the boundary will be close to the 131 dam.

Is there is overlapping of critical thicknesses, the precipitation, if any, could be of any type depending on the surface temperatures.

C. Local effects and partial thicknesses technique.

Some local effects will influence on the types of precipitation that the general correlations would indicate: valleys, mountains and large water bodies are the most important ones.

The presence of a valley tends to push the precipitation types boundaries towards higher low level thicknesses, whereas mountains and large water bodies have the opposite effect.

3.5 Forecast of partial thicknesses.

Nowadays, numerical models generally have enough sharpness and accuracy to allow a confident use of forecast partial thicknesses. Even though models still experience some biases when one looks specifically at forecast vertical temperature profiles for specific grid points, the use of 150 mb thickness layers filters out some of the systematic errors: for example, a small temperature bias at a specific level will generally have very little impact on the value of a 150 mb thickness. Also, if opposite biases appear in the same layer, they will compensate one another.

Even though we do not have a statistical verification of forecast partial thicknesses for the two quite recent versions of the Canadian models (RFE: 90-03-29, GLOBAL: 91-03-12), a few case studies and huge operational use indicate that forecast values are quite accurate up to 24 and even 36 hours in most cases.

3.5 Simultaneous use of partial thicknesses and pattern recognition.

The partial thickness technique helps define precisely which region will be affected by freezing rain. On the other hand, the pattern recognition technique may help in the evaluation of the accuracy of the forecast partial thichnesses and it helps adjust them if some cases, especially for longer term forecast (i.e. 36-48 hours). For instance, if an IP case is identified while the forecast partial thicknesses would suggest freezing rain, we can suspect that the partial thicknesses are forecast too far north, particularly at low level. Even with a very good surface numerical prognosis, this may happen due to the presence of a strong cold air advection in the boundary layer. This latter effect is generally underestimated allowing thicknesses to rise faster in the model than in reality. The pattern recognition technique combined with the partial thicknesses, gives very good results in many cases.

4. CONCLUSION

The synoptic pattern recognition technique and the partial thickness technique should be used simultaneously to determine the precipitation types associated with a winter storm in the day to day forecast. Both the synoptic and the mesoscale effects are more or less considered by these techniques and we strongly believe that their use at the Centre Météorologique du Québec by the winter severe weather specialists has raised significantly the overall quality of the forecasts.

The synoptic pattern recognition technique requires local application but we believe a similar approach could and should be developed in each region. The partial thickness technique is, on the other hand, more general and based on the physical structure of the atmosphere making its application possible almost anywhere with some minor adjustments.